

What a 'Web Sensor' can do for 'Sensor Webs'

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Abstract— The Expandable Reconfigurable Instrument Node (ERIN) component and Web Sensor Strand (WSS) technique can be used to enable a local continuum of hydrology measurements. 2nd generation ERINodes, will weigh in at 2-3 pounds, so that they can be mounted on slow and low flying Unmanned Aerial Vehicles (UAVs) which offer a unique viewing angle and an advantageous dwell time for calibrating satellite measurements, plus the local continuum can patch together, in-situ sensors in the sensor web with a remote sensing measurement with higher spatial resolution. For example, one would be able to see under tree canopies and measure the effects of tree cover at the drip-line, seasonal variations (e.g. leaves on the ground), and fresh water tracking in mountainous areas and perform coastal salt/water tracking where it affects human activity, flora, and fauna.

The current technology development has two ERINodes which will demonstrate a Web Sensor Strand by pulsing an L-Band radar simultaneously, and then tagging them precisely with time, position, and pointing data so that the interferometric baseline formed between the two coherent nodes can be captured with backscatter and forward scatter (from the other node).

The paper will report on the current status of the ERIN WSS Technology Development Project and predict its niche in the current NASA satellite mission Aquarius, and Decadal Study missions such as Soil Moisture Active-Passive (SMAP), Snow and Cold Land Processes (SCLP), ICESat-II and Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI).

Keyword-sensor web, web sensor, coherent, radar.

I. INTRODUCTION

The objectives of the ERIN-WSS Program were to demonstrate a technique that could wirelessly connect two independent platforms as a single sensor baseline and enable synthetic aperture analysis at key microwave wavelengths. Miniaturized components can enable small (12 # radiometer nodes demonstrated, radars slightly heavier) to connect in a web of interferometric measurements formed by node motion. This will offer a

unique viewing angle that will calibrate satellite measurements, and “connect the dots” of traditional ground truth with a local continuum of remote sensing measurements.

II. EXPANDABLE RECONFIGURABLE INSTRUMENT NODE (ERIN)

The Expandable Re-configurable Instrument Node (ERIN) is an FPGA-Based Real- Time data logger with a data stream precise time, position, and beam pointing information attached to each radar return pulse. With one node the ERIN controls the L-Band radar front end with a 10 MHz sine synchronous to its own 40 MHz clock. This is done with this commercial-off-the-shelf (COTS), locking circuit, as described in figure 1.

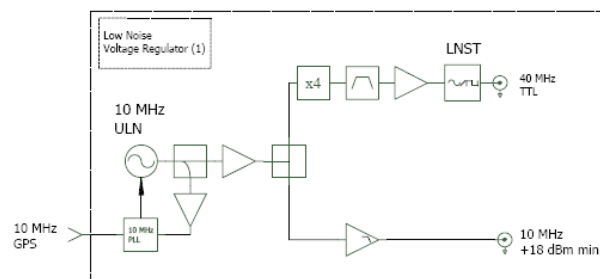


Figure 1: The ERIN Synchronous Control System and LO that derives the radar carrier and mixing signal

From the 10 MHz sine wave output the radar phase lock loop (PLL) transmit 1.26 GHz carrier frequency is derived, and the same 10 MHz reference is split and provides a 1.24 GHz mixing signal to mix down the return pulse to an intermediate frequency between 3-37 MHz.

Meanwhile, the 40 MHz square wave is keeping up to date with the radar and controls the extremely fast modulation switch, with a control signal generated in the FPGA. This fast switch precisely controls the leading edge of a 30 nanosec radar pulse and quickly cuts off the receive window only 100 nanoseconds later. This will gate out the clutter from the tower and boom

truck that are being used as research platforms for the Web Sensor Strand (WSS) demonstration.

III. WEB SENSOR STRAND (WSS)

DEMONSTRATION

The radar return of the monostatic radar has been modeled by the ERIN team to predict these required pulse widths and return gates. Likewise, the precision and noise immunity of a bistatic radar was also carefully modeled to predict back- and forward scatter from two simultaneous transmit pulses. Synchronizing two pulses will be accomplished using the 10/40 plate described in figure 1, and a 10 MHz Rubidium oscillator updated by GPS every second.

This second radar node will be installed not on the single position tower, but on the moveable boom of the boom truck. When the demonstration system is upgraded to 1 cm position determination in the third year of the technology program, we will be able to reconstruct the interferometric synthetic aperture radar to 1/20 of one wavelength using differential GPS (DGPS) techniques already available to us at Goddard Space Flight Center.

IV. A WEB SENSOR'S ROLE IN A SENSOR

WEB

Component by component the ERIN-WSS team has worked to miniaturize the required circuitry of an ERINode. The FPGA-based processor is a design with a path to flight enabled by the Xilinx chip that it uses. The radar application of the VIRTEX 4 realized in the road warrior is already queued up for technology transfer with concurrent SBIR efforts underway at Goddard using the same platform to control radars. Expandable and Reconfigurable, the ERINode Team is also gearing up to support Passive Active Interferometric Radiometers with Interleaved Radars{(PA(IR)²). An example of a small radiometer platform, only 12 pounds, successfully measured brightness temperature data at L-Band. L-Band data can be interleaved temporally between radar pulses to infer a scene change using shorter integration times and interpolate a similar synthetic array. Table I summarizes the graduated requirements of an ERINode that uses different PA(IR)² front ends to measure rainfall, soil moisture, snow, and snow on sea ice and glaciers.

Tying together in-situ ground truth measurements with a true remote sensing measurement capable of comparing dramatically different Earth Incidence Angles (EIAs) flying low and slow, has tremendous scientific potential as a calibrator of the far-away satellite measurements, a resolver of the "mixed pixel", for model validation. Many

strands potentially to create a huge aperture capable of measuring static (not changing in time) targets at longer wavelengths than L-Band, and interpreting tagged integration periods between radar pulses at X-band, K-Band, and Ka-Band.

Below, PA(IR)² resolves the "hillslope scale" enabling Snow and Cold Land Process (SCLP) resolution and interpretation from higher altitudes using the Slow and Low UAV for Snow Hydrology (SLUSH) snow algorithm validated from the "ground up".

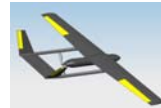
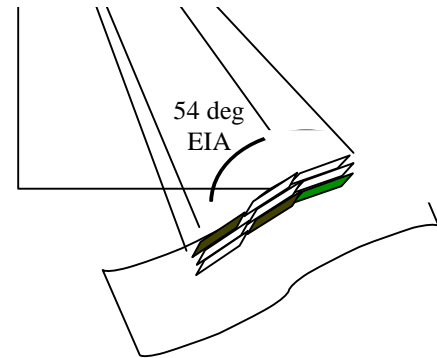


Figure 1: Slow and Low UAV for Snow Hydrology demonstrates how it can look under the drip line and achieve hillslope resolution



For Soil Moisture Active
flying over the

Passive, an ERIN

Foliage and another looking under the drip line will help calibrate these blurry lines and mixed pixels where soil moisture and the global hydrology cycle models need to be calibrated.

The ERINode, when allowed to "stitch" or form an interferometric baseline over every radar pulse can show the true potential of ERIN-WSS Technology. In conjunction with a satellite measurement such as DESDynI, a balloon and UAV combo can map in great detail the dynamics of the ice, and with interleaved radiometer channels, also gauge snow depth, wetness, and extent. This is a great complement to the satellite measurement and can help track the melting sea ice and its impact in specific curvilinear coverage regions such as the coasts of Antarctica and Greenland. Appropriately enough, this use case is called STITCH or Synthetic Thinned Interferometric Tomographic Cryospheric Hydrology, because the platforms stitch these coastlines that are the headwaters of sea level rise due to climate change.

Table 1: ERIN – WSS Technique Applications – Enveloping Use Cases with a miniaturized 2-3 lb. ERINode

Spaceflight Mission Relevance	TRMM also relevant to GPM-SMAP-Soil Moisture Cal	Aquarius SMAP	SCLP	DESDynI
Effort milestones (month-yy)	WSS-S8 Sep-08	WSS-SR Multi-Probe Mar-09	WSS-SLUSH Sep-11 Active:L, 3 Passive:X,K,Ka	WSS-STITCH Sep-12 Active:L, 4 Passive:L,X,K,Ka
Channels	Active:L	Active:L, Passive:L		
Unprocessed Data from Sensors	1.4x10 ⁹ bps	1.4x10 ⁹ bps	1.4x10 ⁹ bps	1.4x10 ⁹ bps
Processed Data from Sensors	200,000 words/sec @ 64-bit words = 1.28 x 10 ⁷ bps	~ X2 2.56 x 10 ⁷ bps	~ X4 5.12 x 10 ⁷ bps	~ X5 6.4 x 10 ⁷ bps
Data from Peripherals other than the Radar	Currently negligible	TBD	TBD	TBD
Data storage (per 20-minute pass)	30 MB	~ 60 M	~ 120 MB	~ 150 MB

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V. BIOGRAPHY

The ERIN Team is a multi-discipline group at Goddard Space Flight Center that applies expertise and experience from Field Programmable Gate Arrays (FPGAs), microwave sensors, differential global positioning system (GPS) receivers, and image processing. The scientific push comes from the soil moisture, snow water equivalent, and sea ice hydrologists.